Fast Response Sensor for the Measurement of the Optical Properties and Carbon Content of Organic Aerosols

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Abstract

In the Phase I SBIR work under contract number N00244-00-P-2504, the feasibility of a protoype instrument, the aerosol vaporization spectrometer (AVS) was evaluated for the ability to classify particles by their incandescent signal. The objective is to provide real-time mass information on airborne black carbon particles. The instrument uses a diode pumped Nd:YAG laser at 1.06 μ wavelength to excite the particles. The scattering signal is monitored from all of the particles, and the black carbon particles absorb sufficient energy to incandesce, and this incandescence is measured by broadband and narrowband detectors. The work detailed in this report, conducted under the optional phase I funding is designed for an accelerated start on the Phase II developments. Detailed documentation and an optical response model of the instrument has been compiled. A PC data system to record particle data has been implemented, and data from standard particles and ambient air recorded.

1.0 Overview

This report summarizes activities on the project option entitled, "Fast Response Sensor for the Measurement of the Optical Properties and Carbon Content of Organic Aerosols" The initial work was conducted under the Navy contract N00244-00-P-2504 as an SBIR Phase I project. The goal is to evaluate a prototype instrument, the aerosol vaporization spectrometer (AVS), that uses a patented sensing technique to classify particles by their incandescent signals.

A schematic diagram of the instrument is given in Figure 1. Aerosol particles cross a 1.06 μ laser beam, and black carbon particles will absorb sufficient energy to be heated to the incandescence point. The scattering signal, broadband and narrow band incandescence signals are collected, and there is the option of measuring the infrared incandescence.

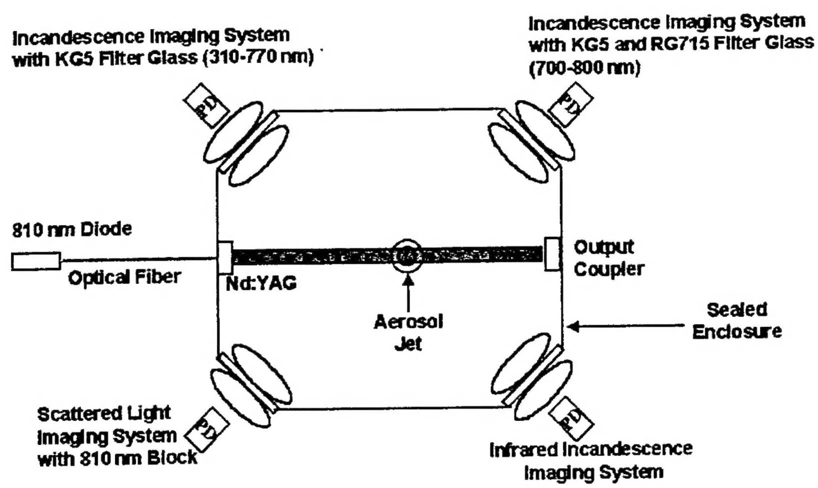

Figure 1
Diagram of the Aerosol Vaporization Spectrometer

2.0 Activities

A major effort was documenting the optical and electronic systems for the AVS, modeling the optical response of the scattering and incandescence channels. When the AVS was received, the system was operational, but there was limited documentation. The unit had evolved in the laboratory, and changes in circuitry and operating parameters had not been recorded. The optics and electronics of the system were completely dismantled and critical parameters and component values documented. In addition to the

documentation, this provided valuable mechanical experience on the cleaning, setup and alignment of the AVS. It can now be considered to be operating routinely, and if adjustments need to be made, they can be made in minutes as opposed to hours required previously.

The optical system of the AVS has four ports available for measurement. Presently one of these is used for the scattering channel and two of them are used to measure the incandescence. The fourth port is used for a video camera that allows a direct look at the aerosol jets and the laser beam. The spectral ranges are defined with colored glass optical filters, and are basically from 300-800 nm for the broadband incandescence and from 700-800 nm for the narrowband. The scattering optical channel covers the spectral range from 800-1100 nm. The relative response of these three channels is shown in Figure 2. The laser pump radiation is at 810 nm and the laser operates at 1064 nm.

In sampling known particles such as polystyrene latex spheres or carbon graphite, the response of the AVS is well defined. The signal is only seen in the scattering channel for the PSL and for the graphite, a majority of the signal is seen in the incandescence channels with a truncated response in the scattering channel. In sampling ambient air, particles can clearly be identified as falling into either strongly scattering or strongly incandescent, but third category is also observed, that has strong scattering, no incandescence in the broadband region and moderate incandescence in the narrow band region. This is surprising as the response of the narrowband and broadband channels overlap and it would be expected that a response would be seen in both channels. The gain of the two channels is similar, so this is not masking the response in the broadband channel.

A clear short coming in the current optical system is the use of the colored glass filters that do not sharply define the optical regions sampled. A series of interference optical filters have been identified that have half bandwidths of 50-70 nm with transmission of 75 % or more. These have been ordered to cover the wavelength range of 717-783nm, 818-886 nm, and 1059-1069 nm. The last filter will be used to better isolate the scattering signal and the other filters will be implemented in the narrowband incandescence channels .

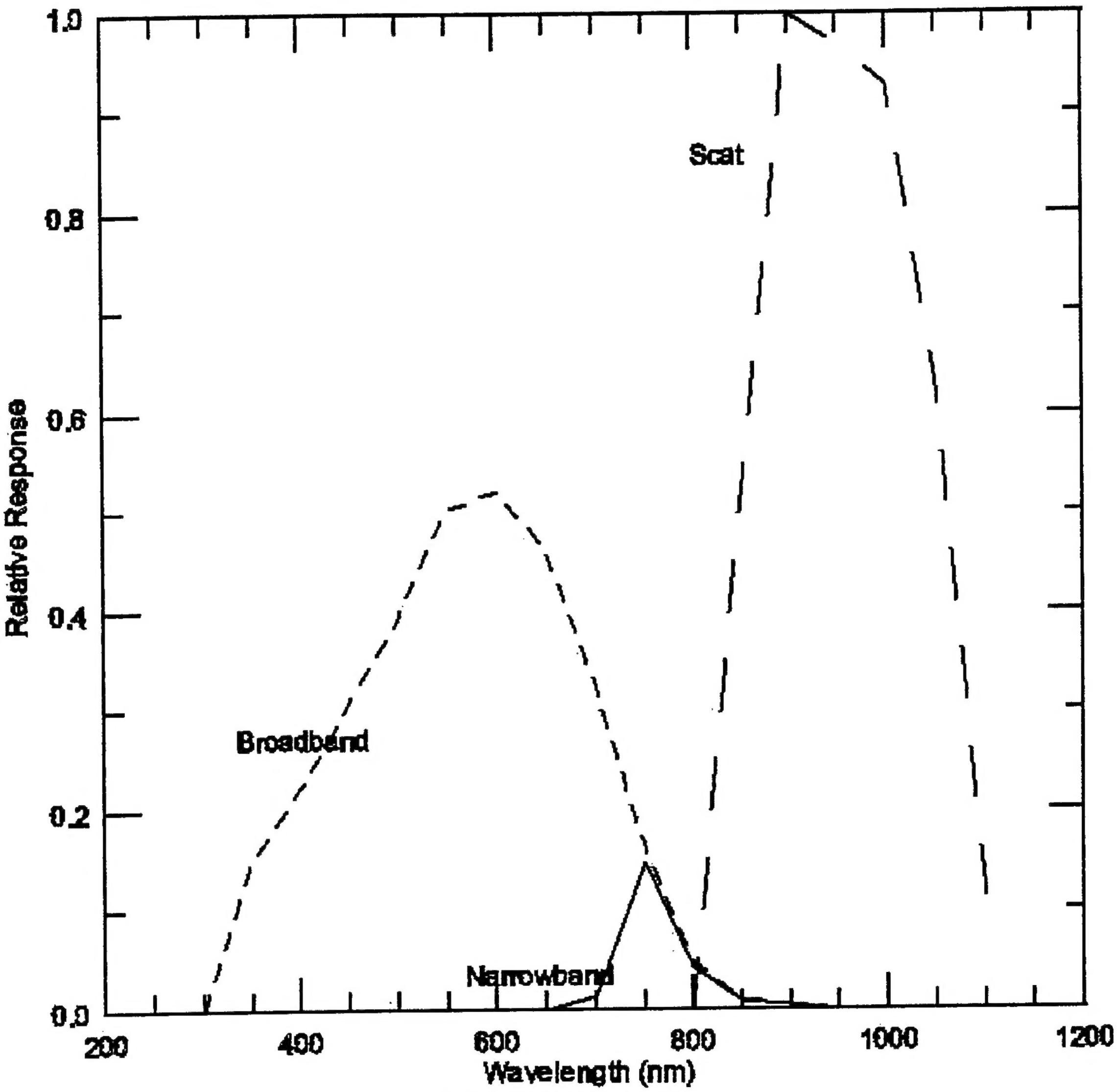

Figure 2. Optical response of the AVS instrumentation.

The other actvity has focused development of data acquisition and processing software for the AVS. A data acquisition system utilizing a National Instruments 6110E high speed A/D board has been setup. The important aspect of this A/D board is the ability to sample four A/D converters simultaneously at up to 5 MHz speed. Since exact time synchronization of the signals will be necessary for the data analysis, this A/D board will be an important component of the system.

The data acquisition software will operate in a triggered mode, using the

scattering signal as the trigger. All other signals will be time referenced to this signal. The data acquisition will terminate when the scattering signal and the other incandescence signals have dropped to some preselected level.

Initially the data processing will be done in a two pass process, first acquisition of the data, and then reprocessing of the file to analyze the signals. The data processing will examine the signals for peak shape, peak width, height, area, and time to maximum from the initial trigger point. Since each particle will generate three signals, scattering, broadband incandescence and narrow band incandescence, a matrix of these relationships can be made to examine the response for each of the different types of aerosol particles. Once the optimum classification scheme has been established, the data processing will be implemented in realtime to provide immediate response on the aerosol composition.

The first part of the AVS data system is now operational, and the capability to record and playback particles is in place. Data is being recorded at 5 MHz for three channels, and then analyzed for particle events and these are stored in a file. The Figures 3, 4, and 5 individual particle measurements for PSL, graphite carbon, and ambient air particles. The ambient air measurements clearly show particles that are inorganic and simply scatter light or are mostly carbon and incandesce. The data for the particle shown here is interesting, in that it is most likely a mixed particle, having a strong scatter signal and also a short incandescence signal indicating the presence of some carbon.
In the attached figures, the trace labeled scattering is the signal measured at 1.06 μ, the laser wavelength. The broadband signal is measured between 300-800 nm and the narrowband signal is measured between 700-800 nm. The response on the Y axis is in counts for the A/D, and there are different gains on the amplifiers, so each channel has a different response. The jagged nature of the scattering peak indicates that the Nd:YAG laser may have other modes operating than TEMoo, and that additional tuning is necessary.

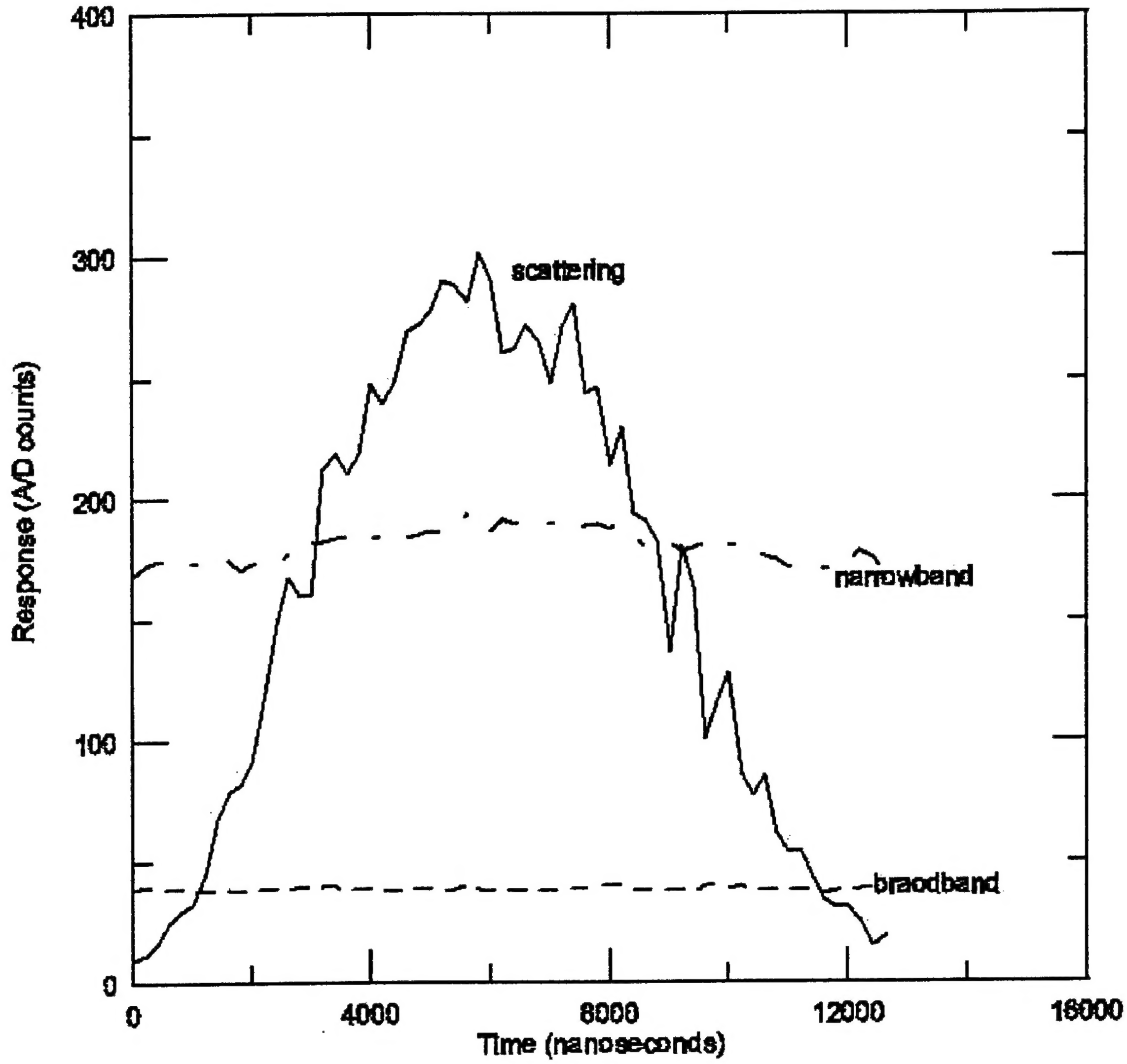

Figure 3. Response from a 0.596 micron polystyrene latex particle

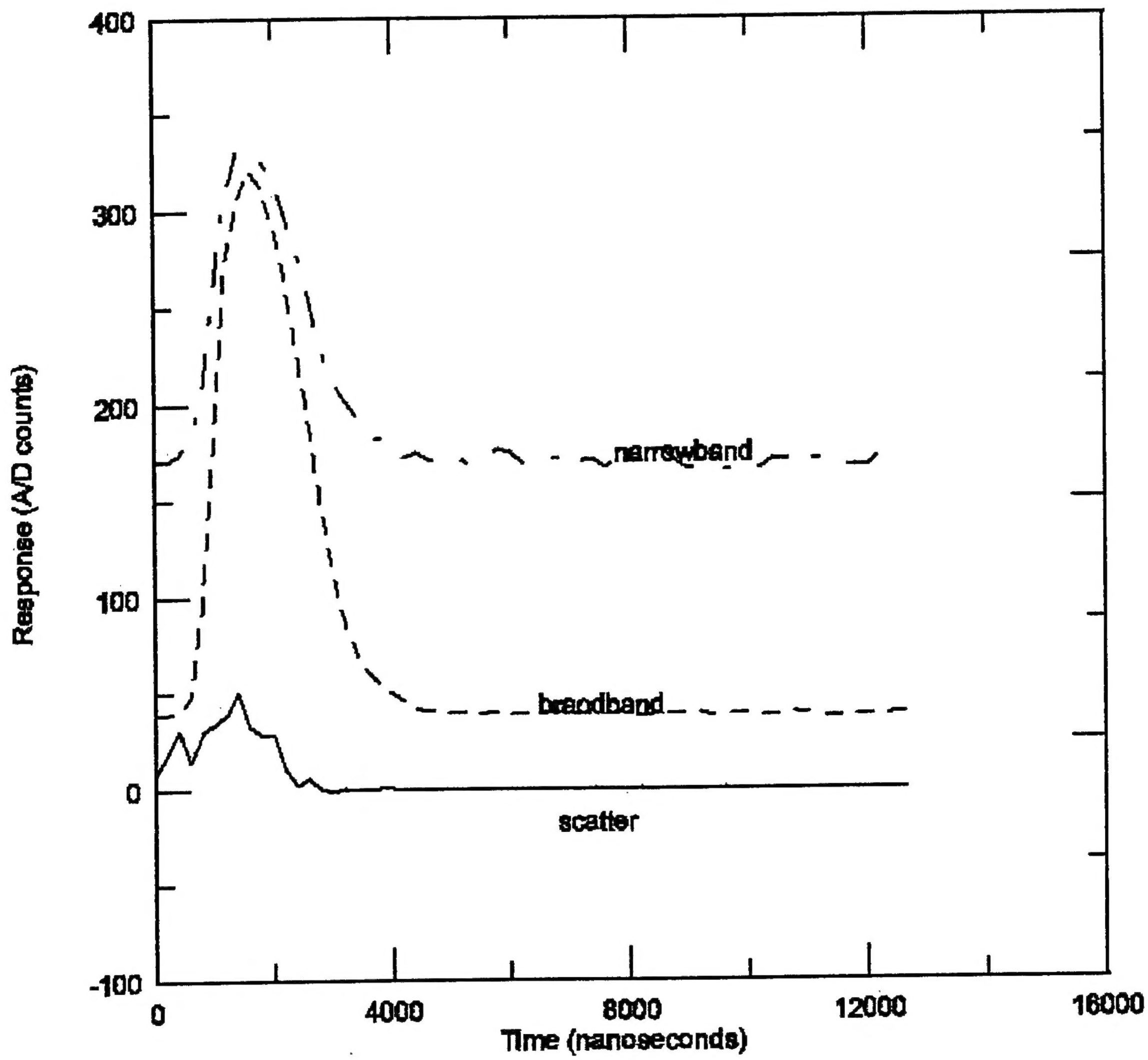

Figure 4. Response from a graphite carbon particle, size unknown

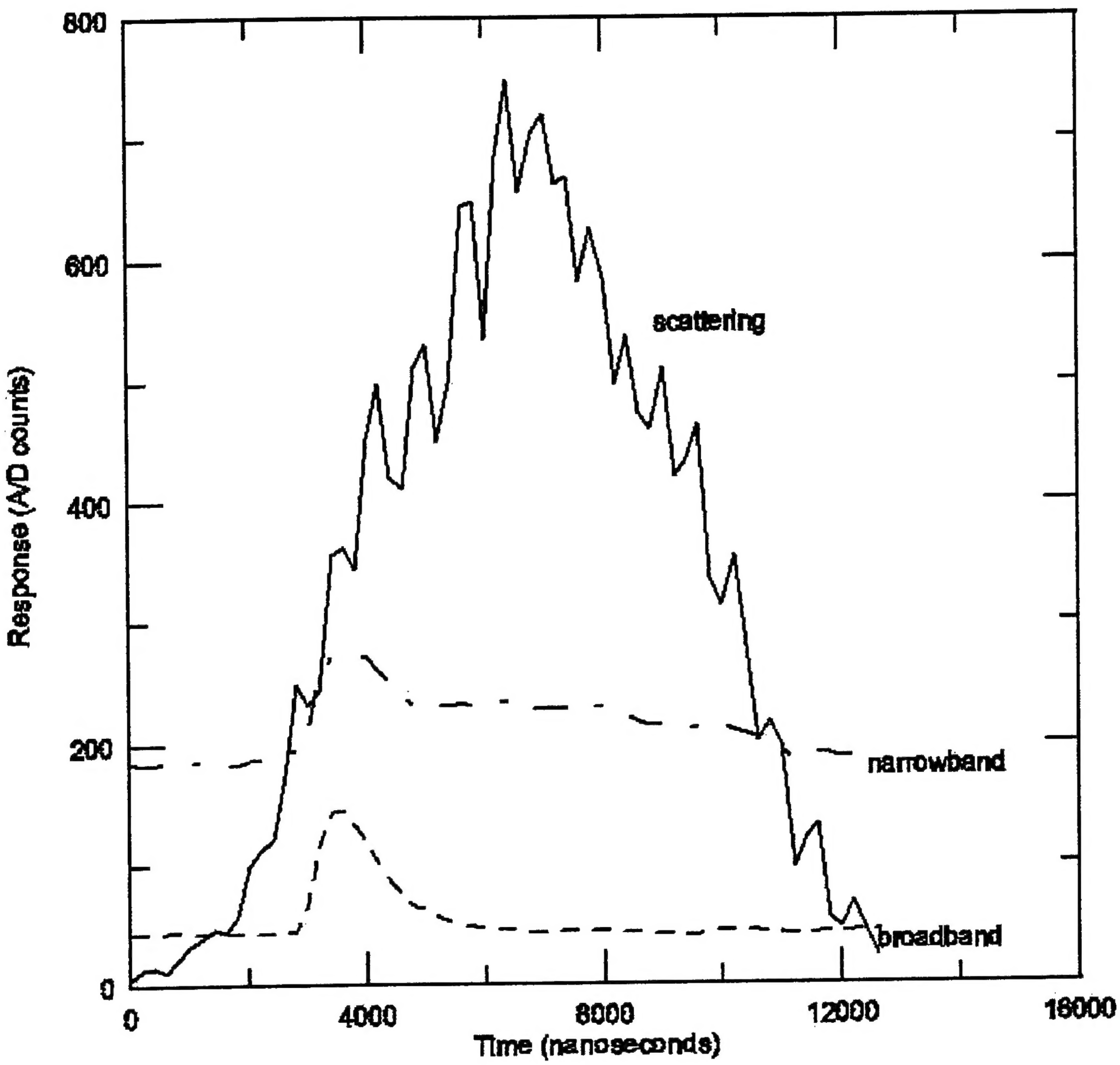

Figure 5. Response from ambient air particle, showing a mixture of carbon and refractory materials.

The AVS instrumentation has now been adequately documented, and the necessary optical components procured to better define the response regions. The first phase of the data system is now operational, and recording can be made directly from scattering and incandescence channels.

Exhibit A

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